AD-A159 946 INVESTIGATION OF RAPIDLY QUENCHED RARE EARTH IRON ALLOYS FOR PERMANENT MAGNETS(U) KANSAS STATE UNIV MANHATTAN G C HADJIPANAYIS JUN 85 N00014-83-K-0290 1/1

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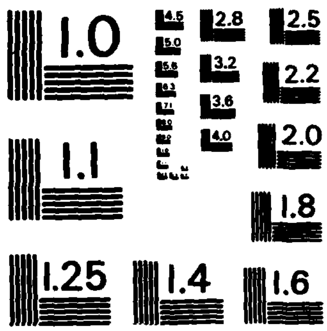

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TITLE: Investigation of Rapidly Quenched Rare Earth Iron Alloys for Permanent Magnets

ONR CONTRACT NO: N00014-83-K-0290

PRINCIPLE INVESTIGATOR: G. C. Hadjipanayis

ONR SCIENTIFIC OFFICER: D. Polk

Final Technical Report

June, 1985

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It was early in 1985, when we demonstrated under an ONR contract the potential of ~~FeNd~~ (Pr) B (Si) alloys for permanent magnet development. The progress under consideration was initiated in April 1983, to study the properties of these materials, in more details and in particular to understand the origin of magnetic hardening by correlating the magnetic properties with the microstructure determined by transmission electron microscopy.

The magnetic properties of melt-spun Fe-R-B alloys have been examined in the whole rare-earth series. The tetragonal $Fe_{14}R_2B$ phase occurs in all alloys studied except in Eu and Yb containing alloys. The Curie temperature of this phase increases from about 170°C in $Fe_{14}Ce_2B$ to 375° for $Fe_{14}Gd_2B$ and then decreases for the heavier rare-earths and is only 320°C in $Fe_{14}Ho_2B$. In heavy ~~rare-earths~~ approx., a second phase with a higher Curie temperature (~470°C) has also been observed. The nature of this phase is not yet known. The magnetic hysteresis properties of melt-spun Fe-light rare-earth-boron alloys were examined and maximum coercivities were obtained in Pr and Nd-containing samples. The coercivities were found to scale with the anisotropy fields, which are estimated to be 40, 80, 40 kOe for $Fe_{14}Y_2B$, $Fe_{14}Nd_2B$ and $Fe_{14}Gd_2B$, respectively.

The effects of partial Fe substitutions with Co, Ni and Mn on the magnetic properties have been examined on melt-spun samples. It was found that 5% Co is enough to increase the Curie

temperature of the tetragonal phase by about 70°C. The Curie temperature of the tetragonal phase increases initially and then decreases with Ni substitutions. On the other hand Curie temperature decreases rapidly with Mn substitutions. Coercivities as high as 10 kOe have been obtained in the crystallized partially-substituted alloys.

The effects of different metalloids on the formation of the tetragonald $Fe_{14}R_2M$ phase are presently being investigated. Preliminary results show a phase in heavy rare-earth-Fe-M alloys (M=Al,C,Si...) with a Curie temperature close to that of the tetragonal 14:2:1 phase. In Fe-Gd-C this phase is also anisotropic but with a smaller anisotropy field as compared to $Fe_{14}Gd_2B$. The higher Curie temperature phase is also observed in these alloys too. We are now trying to identify these phases with x-ray diffraction. We believe that the new ternary phases are also anisotropic. In melt-spun Fe-Dy-Si samples a coercivity of 3 kOe has been obtained.

The origin of magnetic hardening has been examined in both sintered and melt-spun Fe-Nd-B alloys by correlating the microstructure and magnetic domain structure with magnetic properties. Initial magnetization studies show a drastic increase in magnetization with field in sintered magnets and a more gradual increase in melt-spun ribbons. Hysteresis measurements on these samples show a shoulder on the demagnetization curve which appears upon cooling below 150 K. This effect is also reflected on the ac susceptibility studies as

a peak which starts at about 140 K. The peaks are not present in Fe-Gd-B samples. This behavior is also seen on single crystals of Fe-Nd-B and has been attributed to spin-reorientation. However recent neutron diffraction studies did not show any structure around this temperature. Our samples, however, were not single crystals but isotropic melt-spun ribbons and sintered magnets where we have seen several phases with TEM. It could be that this effect is due to the ordering of another phase or it might be due to some anisotropic magnetostrictive behavior which occurs in that temperature range.

Microstructure studies show at least four phases in sintered Neomax samples: The tetragonal $Fe_{14}Nd_2B$ phase with a = 8.8 Å, c = 12.18 Å a tetragonal Fe_4NdB_4 phase with a = 7.09 Å, c = 27.4 Å, a high-Nd-content phase (with cubic symmetry) and some α-Fe. These phases have been also observed in melt-spun ribbons, and the only difference seen is the very fine size of $Fe_{14}Nd_2B$ grains (200-1000 Å) in the crystallized ribbons. Lorentz microscope studies in both samples show domain walls which are smooth inside the grains and end at grain boundaries. Magnetic viscosity measurements, initial magnetization studies and Lorentz microscopy all indicate domain wall pinning at grain boundaries. We are presently trying to obtain some high resolution TEM micro- graphs to analyze the grain boundaries and determine the pinning sites.

Honors Received by Program Participants

1. Intermag Conference, Philadelphia (1983). Invited talk on "Magnetic Hysteresis in Rapidly Quenched Rare-Earth Alloys."
2. Magnetism and Magnetic Materials Conference, Pittsburgh (1983) "Cobalt-Free Permanent Magnet Materials Based on Iron-Rare Earth Alloys".
3. American Physical Society Meeting, March (1984) Invited Talk on "Magnetic Hardening in Rapidly Quenched Transition. Metal-Rare Earth-Metalloid Alloys".

Presentations

1. Magnetism and Magnetic Materials Conference, Pittsburgh (1983), Magnetic Hardening of Rapidly Quenched Fe-Pr Alloys".

Publications

1. Appl. Phys. Lett. 43, 797 (1983)
2. J. Magn. Magn. Mater. 40, 278 (1984)
3. J. Appl. Phys. 55, 2073 (1984)
4. J. Appl. Phys. 55, 2088 (1984)

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